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ABSTRACT

This paper investigates how recent changes in the telecommunications industry are likely to affect government research and development policies by analyzing how changes in the market structure--in particular, increased competition in the industry due to domestic deregulation and international competition--change the political economy of government research and development. The first of four major sections of the paper considers the research and development problem, presents statistics to provide a context for concerns relating to international competitiveness, and considers potential reasons for the underprovision of research in the telecommunications industry and for singling out telecommunications for special treatment by the federal government. The second section summarizes the theoretical issues that underpin the political economy analyses, and suggests that an important motivation for government actions in this area is based on the specific requirements of government, and hence differs from those of private, profit-maximizing firms. The third section applies these models and theoretical propositions to the problem of government research and development, drawing examples from a variety of federal programs. The fourth section turns to an application to the current telecommunications industry, and concludes by recommending places where federal intervention is likely to be valuable for enhancing research and development and innovation in the telecommunications industry. The text is supplemented by one table, and 23 references are provided. (EW)

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Government Research and Development Policy for
Telecommunications

Linda Cohen/1/

This paper investigates how recent changes in the telecommunications industry are likely to affect government R&D policies. The goal of the paper is to analyze how changes in market structure -- in particular the increased competition in the industry due to domestic deregulation and international competition -- change the political economy of government R&D.

The paper proceeds as follows. Section 1 considers the R&D problem. Summary R&D statistics are presented to provide context for concerns relating to international competitiveness. The section then turns to potential reasons for underprovision of research in the telecommunications industry, and for singling out telecommunications for special treatment by the federal government. Section 2 summarizes the theoretical issues that underpin the political economy analysis. The hypotheses that underly the analysis are that the motivations of government actors are based on specific requirements of government, and hence differ from those of private profit-maximizing firms. Chief among these are the need of legislators to be reelected by specific groups of constituents, and the need for coalitions of actors within government (particularly, within the legislature)

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to agree on a line of action. In section 3, these models are applied to the problem of government R&D, drawing from examples from a variety of federal programs. Section 4 turns to an application to the current telecommunications industry, and concludes with recommendations of where federal intervention is likely to be valuable for enhancing R&D and innovation in the telecommunications industry.

1. Problems with the Private Provision of Telecommunications R&D

By the mid 1980s, American manufacturers lost market shares in fields traditionally dominated by them, ranging from automobiles to steel to woman's clothing. Exports even in high-technology failed to keep pace with imports, and by 1986, the U.S. was for the first time a net importer, with a trade deficit in high-technology products of over \$2 billion./2/ Competitiveness had entered the national vocabulary.

International competition adds fuel to discussions about the adequacy of investment in research and development (R&D). Two striking features of U.S. R&D spending emerge in international comparisons./3/ While the U.S. devotes a similar proportion of GNP to total R&D as do Japan and West Germany -- 2.69% of GNP, compared to 2.77% for Japan and 2.67% for West Germany -- it devotes far less to civilian R&D. In 1985, total civilian R&D expenditures in the U.S. were estimated at 1.86% of GNP. The

2. Science and Engineering Indicators-1987, U.S. National Science Board, 1987. p. 313.

3. The information in the remainder of this paragraph is from Science and Engineering Indicators-1987, *ibid.*, pp. 235, 236, 237, 265.

commensurate percentage is 2.75% for Japan, and 2.53% for West Germany. Indeed, federal spending, which accounts for about half of U.S. R&D expenditures, has shifted from civilian to defense activities. In 1970, defense R&D expenditures accounted for 48% of the federal R&D budget; by 1987, that number had risen to 64%. Federal civilian R&D expenditures dropped from \$19.2 billion in 1970 (in 1982 dollars) to \$17.1 billion in 1986.

Second, the rate of R&D investment has increased much faster among our competitors. Total annual R&D expenditures in the United States increased 55% in constant dollars between 1970 and 1985, from \$62 billion to \$96 billion. Japanese expenditures climbed 190% during the same period, from about \$12.4 billion (1.85% of GNP) to \$36 billion.

Public support for research has a solid economic rationale. Absent government policy, private firms are likely to invest less in R&D activities than is socially desirable. For a variety of reasons, the private returns to R&D investment are typically less than the social returns. R&D results are frequently valuable to unexpected applications, for different products, firms, or industries. Research results may well be valuable, but to someone other than the firm that made the initial R&D investment. Furthermore, once a process or product is known, it can be imitated without duplicating the entire development effort. Unless the expected return is very large, the optimal strategy for all firms is to wait for someone else to do the R&D. In competitive industries, research returns may be captured by competitors, by downstream firms, and by consumers. Finally,

information from R&D is a public good, so that efforts to limit its dissemination and enhance appropriability are socially inefficient.

In the United States, government policies to promote R&D investments have included patent protection and antitrust exemptions for R&D joint efforts, tax credits for private R&D expenditures, direct federal grants to industry, and direct federal research, development and demonstration programs. One of the first examples of a government program to demonstrate new technology was in communications: in 1842 Congress appropriated \$30,000 to construct a telegraph line from Washington, D.C. to Baltimore. It subsequently operated the line for a year at no charge to users. (Brock (1981))

Communications technology is singled out for public support because of a number of special characteristics. First, communications and information technology is a key component for future generations of a variety of products. Communications and information technology plays a major role in new products by enabling new services and functions, and these technologies are expected to decline in cost in the future. Costs have declined dramatically in the communication/information field during each of the decades after World War Two, and this trend should continue. Similar cost declines are not anticipated for other inputs to new technology. Energy, for example, is likely to become increasingly expensive, as will other resources that are depletable or fixed in total supply. Thus the cost of new products will be lower to the extent that communications and

information technology is incorporated or substituted for traditional inputs. Consequently, competitiveness over a range of industries will to a considerable extent depend on technological competitiveness in the communications industry./4/

Second, the government is itself a major consumer of advanced communications technology. The federal government is a major user of communications and information technology in all of its departments. As demands for government provision of services have increased, so have its demand for communications technology. This is of course critical in defense, where advanced defense technology relies on advanced communication technology, and where more broadly defined communications are key to the provision of traditional defense activities. Communications technology -- the more advanced the better -- contributes to the success of a number of government's more glamorous projects, including space exploration and other scientific endeavors.

Third, the federal government plays a major role in negotiations for coordinating international aspects of communications policy, such as spectrum allocation and international standards setting.(Macauley (1987)) The dominant position of the United States in communication technology in the past contributed to both the government's ability to formulate a favorable position and to enhancing its influence in

4. An implicit assumption behind this reasoning is that U.S. firms are disadvantaged if they have to buy technology from foreign sources. This could result from restrictive trade policies, but probably the more important reason is the subtle effects of understanding the technology better when it is developed domestically, e.g., from know-how and sophistication within the domestic workforce. (OTA(1985))

international negotiations. The federal government justified the National Aeronautics and Space Administration's (NASA) communication technology R&D role up to the mid-1970s by recognizing the contribution of communications R&D to American influence in international agreements. (Cohen and Noll (1987))

Finally, the telecommunications industry remains heavily regulated, despite the recent trend toward less regulation. With regulation comes two sources of uncertainty for the potential inventor: the invention may need regulatory approval, which can take an indeterminate amount of time to secure, and regulated firms may need approval of investment plans to acquire and use new technology. Regulatory delays for use of new technology can be very substantial, as was the case for cable television and domestic satellites during the 1960s and 1970s. (Noll, Peck, and McGowan (1974)) Consequently, government regulation may retard the dissemination of new technology and depress incentives to invest in R&D.

Juxtaposed to these factors that underlie continuing interest by the government in advances in communications technology are a series of concerns that the provision of R&D may not be adequate. In addition to the general funding trends discussed above, the overall balance of federal R&D funding between defense and civilian activities may be detrimental to civilian applications. (OTA(1985)) While the likelihood of communication technology spillovers in either direction is unclear, and is not a topic that can be resolved here, one line of argument holds that as military and civilian applications

become specialized, the payoff from defense expenditures to civilian communications is increasingly smaller.

Space communications R&D in particular has been in disarray for over ten years. NASA's communication satellite R&D program, which was a notable success during the 1960s, ended in 1974. The follow-on program (the Advanced Communications Technology Satellite) has had a rocky history, and the extent of subsequent efforts by NASA are currently uncertain. The celebrated reentry of America into space with the September, 1988 shuttle launch provides access for the first time since the Challenger accident in 1986; however, there is currently a substantial backlog of payloads. Uncertainty over future launch schedules as well as prohibitive insurance costs have stymied private efforts to invest in new space communications technology.(SAB (1988)) Such uncertainty diminishes incentives to invest in R&D leading to innovations that will use future space launches.

Finally, and perhaps most importantly, the telecommunications industry in the United States, and thus the private provision of R&D, is in flux. The impact of the divestiture of AT&T and subsequent changes at Bell Labs on R&D and innovation is unknown, although major changes in the two years following divestiture were not evident.(A. M. Noll (1987)) Increased telecommunications competition has thus far created markets for new products, and hence enhanced incentives to invest in short term product-oriented R&D. However, we do not yet know the impact of changed market structure on investment in basic

scientific research that leads to long-term fundamental innovations.

2. Congressional Politics and Government R&D /5/

In the following section, the implications of these models for government R&D activities are analyzed. Because it best demonstrates the implications of positive political theory, the section concentrates on Congress, and on direct government programs for the provision of R&D. The concluding section then turns to alternative government policies.

The basic building block for these models -- and the necessary background to the ensuing discussion of R&D -- is how costs and benefits of government programs are perceived by voters and factored into their decisions about whether to vote for a legislator. Three dimensions of the political calculation of program costs and benefits are important to this discussion: the distribution and definition of costs and benefits, their timing, and the likelihood that they will be an important factor in the overall assessment of the legislator by his constituents.

Distribution of Benefits. When a constituent is employed on a project, or when his district receives substantial benefits that effect the overall economic health of the area (e.g., a military base), or when he is a member of a group that benefits from a government policy (e.g., Social Security), or when his business benefits (e.g., trade policy, protective regulation) then the constituent is likely to support the program, and to

5. This section draws heavily from joint work by the author and Roger Noll, (Cohen and Noll (forthcoming)).

want his representative to support it as well. Alternatively, if a program imposes costs on a constituent, then he is likely to oppose it whatever the net social benefits. In either case, two conclusions follow: first, program expenditures, which are economic costs, are perceived by some voters as program benefits, and second, legislators are likely to consider the specific geographic distribution of program effects rather than (or perhaps, in addition to) net effects on the country as a whole. (Weingast, Shepsle, Johnsen (1981))

Timing of Benefits. The second factor that distinguishes a political assessment of programs from an economic assessment is the timing of costs and benefits. In short, future benefits are less attractive for politics than for private industry. This effect derives from interactions between legislatures, voters, and periodic elections.

Federal programs require annual appropriations. Multi-year projects cannot be firmly committed to at the outset. Because the makeup of the legislature changes over time, and because expected economic success is at best only one factor that determines political support, added uncertainty is introduced over whether a program will survive, even if it appears to be going well. One bias that results is that voters are expected to discount the present value of a program by a factor that reflects the necessary lack of commitment to it by the legislature. Furthermore, voters can more easily evaluate legislators on the basis of what has happened than on the basis of policies whose effect on future conditions is probably uncertain. Finally, not

only do legislatures lack commitment strategies, so do individual congressmen: they need not deliver on election promises. The solution to the principal-agent problem is retrospective voting, i.e., to base current votes on an assessment of past performance rather than campaign promises. These factors all contribute to voters evaluating programs on the basis of short run effects, and consequently, of legislators basing current election strategies on short term deliverables./6/

Career strategies by representatives only partially mitigate this bias. While representatives plan for future elections, including perhaps the election that follows the anticipated completion of the project, they first have to be reelected in earlier elections. Consequently the electoral system overall provides incentives for extra discounting of future benefits.

Saliency. The final building block is saliency, used here to refer to the extent to which issues are important in the voting decisions of constituents. Political saliency considerations introduce two asymmetries into the calculation of costs and benefits. The first can be termed a threshold effect: programs are politically salient only when they exceed some level of importance within the district. The second is that costs imposed on constituents are likely to be more salient than benefits of equal size.

Three lines of reasoning contribute to the threshold hypothesis. First, the direct electoral view holds that voters

6. A large literature exists on retrospective voting. See, e.g., Fiorina (1981), Downs (1957). For specific applications to legislative incentives, see Cohen and Noll.

only notice fairly major projects, and vote on the basis of them. Small benefits or costs rarely effect individual voting decisions.

Second, interest group models of government hold that actions are taken in government to benefit organized interest groups, who assure the provision of public goods to all members of the group. (Stigler (1971), Peltzman (1976)) When the goods in question are public, individual benefits may not be large enough to make it worthwhile for a single person to shoulder the burden of organizing the group, and furthermore, the cost of dividing up the expense increases with group size. Consequently, many such groups won't form. The smaller the group needed -- which is to say, the larger are individual benefits relative to the cost of organization -- the more likely the group is to form and exercise political muscle. (Olson (1965)) The argument applies at a district level as well. Politically active groups within a district are more likely to coalesce when the district distributional impact of a program is large.

Third, studies of congressmen conclude that many of the actions they take are based not on expressed wishes of constituents, but rather on what they expect those wishes might be if their constituents ever found out about the program. (Fenno (1978)) Programs with large distributional impacts are more likely to be the focus of congressional campaigns, and hence it is more important for legislators to adhere to the expected wishes of constituents on such matters. Moreover, if voters become aware of a political issue because some hopeful challenger

is bringing it to their attention, then they are in general more likely to be aware of programs about which they are unhappy: dissatisfaction is the grist of challengers. Legislators are consequently likely to be more sensitive to programs that impose substantial costs on their constituents than to those that grant similarly sized benefits.

3. Political Economy of Federal R&D Programs.

a. Political Support for Research and Development

Models of government behavior predict the following general conclusion regarding R&D policy in the federal government: a federal R&D program is a shaky enterprise. The distribution and timing of an R&D program's expenditures and (economic) benefits are not optimal from a political point of view, and indeed, distributional consequences of a program can often be detrimental to the political calculus even if a traditional economic cost-benefit analysis would recommend pursuing the program.

At the start of an R&D program, expenditures are usually not a political plus. As is discussed below, this changes as programs progress, however, at least at their start, these programs lack political appeal on pork barrel grounds. A typical R&D program starts out with the investigation of numerous concepts and relatively small expenditures. At the conclusion of this "research phase", the more promising ideas are investigated at a larger pilot plant stage. The second stage of R&D involves considerably more expense, and the possibility for some politically attractive contracts. Successful programs may

proceed to demonstration. Demonstration plants incorporate important features of commercial sized plants or projects, and are expensive. In most programs, demonstrations are limited to one or very few separate projects. (Scherer (1984), ch 1)

This characterization of R&D describes the expenditure problem. Because of uncertainty in R&D, contract beneficiaries are not known at the outset, and even if known will not receive substantial funds until later in the project. Consequently, expenditures alone cannot justify the programs, for alternate transfer programs with more attractive timing and greater certainty over recipients provide direct ways of targeting the distribution of federal largesse.

Basing political support on the ultimate economic benefits entails political problems owing again to timing and distribution. To the extent that innovation benefits society, the benefits are likely to be diffused rather than concentrated, and thus fail a threshold test of political relevance. Future benefits are, of course, in the future, and hence subject to additional political discounting.

To the extent that the benefits are interesting to industry, R&D programs run into two important problems. When a program involves discrete components (particularly at the demonstration stage), government may have to choose a winner from among firms bidding for the primary contracts, who not only gets a juicy contract, but gets a leg up in the new technology and hence a competitive advantage. Such programs are therefore likely to create industry losers as well as winners. Because of political

asymmetries in the evaluation of program costs and benefits, such programs are expected to be unstable. The U.S. government is usually very sensitive to charges of unfair advantages resulting from government intervention in the market.

More generally, to the extent that programs benefit all players within an industry, rather than identified subgroups, the program is more feasible politically. Market organization is consequently important to the discussion. If the market is regulated or monopolistic, so that firms are guaranteed sales whatever the outcome of the program, then discrete projects are feasible. If the market is competitive, then programs that work tend to have one of two structures. Either they include enough pieces that all players can participate in one of them, or they are centralized, with all players cooperating. Such cooperation has been more forthcoming in regulated industries, such as electric utilities, but more recently examples have occurred in the electronics field as well. These projects are further discussed in section 4.

The second political problem with successful R&D programs is that fundamental innovation is likely to change the structure of the industry in which it is used. Industries that rationalize regulation on the basis of scale economies are likely to oppose projects that, if successful, would reduce the extent of relevant scale economies. Consequently, such industries are unlikely to be enthusiastic about some programs that are attractive from a social standpoint. The situation is not precisely symmetric with respect to competitive industries. Such firms will oppose a

program that is anticipated to increase scale economies in the industry only if they believe that they will not be among the remaining firms after the shakeup. Thus, opposition to programs on these grounds is more likely to come from industries that are currently monopolistic.

NASA's satellite R&D program is a case in point.^{7/} In the early 1960s NASA successfully launched a geosynchronous satellite into orbit. The agency followed up this feat with an acclaimed series of research satellites, laying the foundation for future applications in communications and meteorology. As a result, the satellite supply industry moved from a single provider -- Hughes Aircraft, which had proposed and built the first series of NASA satellites -- to a competitive industry with over a half a dozen firms interested in building satellites and participating in NASA's research program. The second series of NASA satellites was subject to competitive bidding for prime contractors. However, because of the bulkiness of the technology -- one reason why the government was involved in the field -- a single firm had to be chosen to be the prime contractor, and it was widely believed that this would give the winner a distinct competitive advantage for the next generation of satellites. The ensuing contract battle, involving lawsuits, government investigations, and substantial bad publicity for NASA, significantly reduced government enthusiasm for the program. The second phase was trimmed back, and the program ended in the early 1970s. Efforts

7. This discussion is drawn from chapter six in Cohen and Noll, *ibid.*

to restart it have been plagued with similar squabbles among the satellite manufacturing firms.

At least at their outset (i.e., before there is porkbarrel support) major federal R&D programs tend to be associated with unusual political salience that inspires a national consensus in a particular area, such as energy in the 1970s, and space in the preceding decade. Such motivation, however, shifts over time often unrelated to the success of the program. For example, while many critics were unhappy with the synthetic fuels program on efficiency grounds, the rapid demise of the Synthetic Fuel Corporation in the early 1980s resulted from dropping energy prices undermining the belief that energy independence was a national imperative, and not from the actions that the SFC had taken by that time. Consistent, long-term R&D support is relatively unlikely.

The Synthetic Fuel program demonstrates another related point. When neither program expenditures nor economic results are sufficient to generate a majority coalition of supporters within the legislature -- as is the case for most R&D programs -- support coalitions are usually tied to ideological beliefs. However, the ideology that underpins public support for R&D changes with the different stages of an R&D program. Appropriability concerns are paramount in the rationale for federal support of basic research and science, so that political support for such programs does not conflict with free market concerns, or general opposition to government interference in the market. Government support for later stages of research,

however, implies a more activist role. Ideological support for demonstrations rests on two factors, both of which are usually involved in public rationales for such programs. One is that the indivisibility of investments leads to particularly risky assessments by firms for demonstrations. The second is that a national emergency has created a social imperative for speedy commercialization.

In the synfuel program, ideological conservatives were more likely than liberals to support the more research-oriented work carried out by the Department of Energy. The situation switched, however, following the 1979 energy crisis, when the program was reoriented towards short term commercial development. The support coalition then rested on the liberal wing, who, however, defected with the decline in oil prices. One result was that the program relied on shifting coalitions, and consequently lacked coherence in the R&D process. Another was that the later coalitions were not powerful enough to maintain the program, and, at least according to some assessments, valuable components were lost when the program was terminated in the early 1980s. Ambitious, long-term projects, that are intended to move through multiple phases of research, are very unlikely to maintain a coherent, stable structure. The lesson for federal R&D programs in telecommunications should be clear.

b. Government R&D Program Management

An apparent contradiction emerges from studies of big government technology demonstration programs. That is that demonstrations, once underway, are extremely difficult to

reorient or cancel even when the economics of the situation alter dramatically. Thus the space shuttle program continued doggedly during the 1970s even though cost overruns and disappointing technical results clearly indicated that some program modifications were in order./8/ The federal program to develop a super sonic transport during the 1960s was eventually cancelled - - as was a much bigger project, the Clinch River Breeder Reactor -- but not until years after even the government's cost-benefit studies counseled program changes./9/

These examples refer to project rigidity, rather than program stability. Indeed, once a government R&D program gets underway, it can involve a project that is attractive for pork barrel purposes (big contracts to firms in a reasonable number of Congressional districts). At that point, the project becomes viable based on pork barrel support, which depends on continuation of the particular project plan whatever the ultimate economic implications.

Indeed, a number of characteristics of R&D imply expected trouble on these grounds whenever a program involves a big contracts. R&D results are uncertain. Any initial line of action is expected to be modified before a commercially viable alternative is chosen. Supply and demand conditions are likely to change over the course of the program. Optimal R&D plans entail tremendous flexibility. Juxtaposed to this recommendation is the conclusion that cost overruns are more likely to occur in government programs, and that consequently the existence of pork-

8. Banks, in Cohen and Noll, *ibid.*

9. see also Rose (1988).

barrel based rigidity at the demonstration stage is particularly damaging to R&D prospects.

This harsh assessment is based on several government biases that are likely to result in inefficient program management. First, government is likely to underinvest research, owing either to impatience by legislators, or attempts by bureaucrats to get a project to the major procurement stage, where, owing to additional pork barrel support, it is less likely to be cancelled./10/ Such impatience leads to cost overruns downstream, because research results are needed to efficiently plan the next stage. Sometimes the problems can be massive. Depending on where one allocates blame, the Clinch River Breeder was delayed for between 4 and 8 years in the 1970s because of its inability to get necessary safety and environmental licenses. Initially, the inability resulted from the Atomic Energy Commission's (AEC) lack of information: they could not satisfy licensing requirements because no interim results were available prior to construction of the large demonstration. With hindsight, experimentation on a smaller scale was clearly in order./11/

Second, bureaucracies, and especially scientific bureaucracies, control the research options considered by Congress. Studies of NASA and the AEC suggest that the bureaucracies are motivated by scientific and technological

10. A variant of this conclusion is that programs may be organized to enhance political benefits, by distributing porkbarrel benefits to enhance political support (Arnold (1979)).
 11. This is only one aspect of the licensing story. See Cohen and Noll, *ibid.*, for details.

sophistication concerns rather than commercial feasibility. In consequence, R&D options considered by Congress tend to be biased in the same direction, further diminishing the likelihood of commercial success of direct federal R&D programs. In addition, bureaucracies often want to maintain or expand their programs, and therefore have incentives to bias the information that they provide to Congress. (Niskanen (1971)) Bureaucratic optimism over program results is intensified to the extent that bureaucrats that choose to work in a particular technical area tend to view the technological options as favorable to begin with.

In conclusion, experience over the past twenty years suggests that major commercially-oriented direct federal R&D programs that involve large commercial demonstrations are likely to be very inefficient, and ultimately unsuccessful.

c. Coherent Federal R&D Policy

The federal government has been criticized for the incoherence of its communications policy. (OTA (1985)) Conflicting and contradictory R&D policies have created disincentives for private planning and investment, and have foiled government efforts as well. Perhaps the clearest example is in satellite development: during the 1960s, NASA's successful efforts were prohibited from commercial application by the FCC. Overlapping civilian and defense spending clouds the assessment of R&D efforts, because the government can claim, perhaps justifiably, that cutbacks in civilian spending are compensated by spillovers from defense. This incoherence is not only inevitable, but is likely to become more pronounced with the

changes in the telecommunications industry. Also, and somewhat paradoxically, multiple overlapping agencies are not necessarily bad for R&D, and can parallel some of the strengths of competitive private sector research.

When citizen opinions diverge, and are echoed among legislators, then federal policy is unlikely to be coherent. Congress divides itself into committees with responsibility for legislation, oversight, and appropriations in different areas of federal action. Congressional committees have disproportionate power over areas within their jurisdictions. While jurisdiction over specific bills is usually housed in a single committee, jurisdiction over policy is divided. A division that occurs universally is between authorization and appropriations. In addition, authorization for programs that impact an industry may be housed in a number of different committees. Energy policy in the 1970s was considered by 37 different subcommittees and committees in Congress. Each can propose legislation, and bring it to the floor in such a way that it has a strong chance of prevailing, even though the policies appear in substantial conflict when taken together. Several earnest legislators, on opposing sides of a general policy, can prevail in different committees, and simultaneously on the House and Senate floors.

Expected changes in the communications industry will create greater conflicts. Competition by definition increases conflict. Specifying internationally-oriented policies will do the same between importers, consumers, domestic producers, and federal policy goals in other fields. Adding commercialization goals to

science goals for NASA is bound to cause confusion in policy processes and outcomes. Congress is organized so that small bits of policy address concerns of different groups, resulting in conflicts that parallel conflicts within the population, rather than coherent policy.

Nevertheless, this imperfect world is not all bad for R&D. It has been claimed that government is unlikely to choose winners among R&D proposals. In fact, no-one can reliably choose winners in research. A celebrated example is Western Union's refusal to buy Alexander Bell's basic telephone patents in 1876 for what Western Union considered to be a princely sum of \$100,000.^{12/} The Defense Department turned down Hughes' proposal to develop and launch the geosynchronous satellite that was later NASA's tour de force. Multiple sources for potential funding and development within government, as within private industry, create far greater opportunities for innovation and success. Government inefficiencies may well strengthen R&D opportunities.

Furthermore, coordinated activities require compromises that can constrain program choices to the point of infeasibility. When the Energy Research and Development Administration (ERDA) was established to coordinate energy research, it found its choices in coal research to be constrained by (1) programs oriented towards Eastern coal use; (2) programs that would develop products to substitute, as directly as possible, for imported oil; and (3) programs that would quickly address the perceived national energy emergency. These constraints were

12. Brock, *ibid.*, p. 92.

incompatible: synthetic fuel processes for gasoline and natural gas substitutes that use Eastern coal are still in the stage of fundamental research. Nevertheless, ERDA attempted rapid development of those processes rather than devoting resources to the processes that used Western coal and were much closer to commercialization, processes that would improve obtainable products from Eastern coal, or continuing the more modest long-term research effort in advanced Eastern coal synfuels.

3. Communications Research Policy for Government

The telecommunications industry is undergoing two profound changes: increased internationalization and increased competition. Both changes will involve realignments in political support groups for telecommunications, and alter potential government R&D activities. The previous section argues that coordinated federal programs for research, development, and commercialization are too ambitious to be efficient and successful. More modest government programs, and alternate federal activities, must be considered.

As the industry grows more competitive, the government is unlikely to be successful with research programs that are designed to help specific firms, or that include large discrete projects. Nevertheless, support for basic research are appropriate, even though innovation cannot be promised. Activities that do not single out particular technologies and particular firms are less likely to encounter debilitating political problems and are less susceptible to federal bureaucratic biases.

Of particular interest are policies that can encourage private firms to enhance their R&D programs. Certainly the most important change currently on the agenda is deregulation. Regulation is conceded to inhibit innovation, and deregulation has been hailed as an opportunity for private investment in research and for innovation.

Table 1 contains funding trends for the communications equipment industry (SIC code 366) and U.S. industries for all R&D expenditures and basic R&D expenditures. These figures should be interpreted with some caution, as they rely on company reporting and accounting procedures, as well as company interpretations of what constitutes R&D and basic R&D. The data give little guidance for future funding trends. However, they do suggest that the 1984 divestiture caused development work to be substituted for basic research at least in the short run in communications, as markets for products became (or were anticipated to shortly become) available. The 1984 figures, in addition, reflect uncertainty and chaos in the first year following the industry's reorganization, and uncertainty in the few years prior to the reorganization.

Table 1. R&D Expenditure Trends/13/
(millions of 1982 constant dollars)

	Communications Equipment			All Industries		
	<u>Total R&D</u>	<u>Basic R&D</u>	<u>%Basic</u>	<u>Total R&D</u>	<u>Basic R&D</u>	<u>%Basic</u>
1975	4056	185	4.57	41132	1241	3.01
1977	4054	223	5.50	44374	1355	3.05
1979	4638	249	5.36	48764	1477	3.02
1983	6841	293	4.30	60991	2088	3.40
1984	7133	280	3.93	65771	2383	3.60
Average annual percent change:						
75-79	3.6	8.5		4.6	4.7	
79-83	11.9	4.5		6.3	10.3	
83-84	4.3	-4.5		7.8	14.1	

Whatever the ultimate result of degulation, uncertainty over the future structure of the telecommunications industry inhibits R&D investments. Of course, R&D itself contributes to uncertainty, and the nature of competition and entry in an industry creates uncertainty over who future actors will be. Neither of these is the concern here; rather, it is uncertainty over what the rules for the industry will be, e.g., the extent of competition and the extent of prohibitions to market solutions. Resolution of federal and state policies towards regulation will hence remove an important source of uncertainty for R&D investments. Similarly, in the international field, resolving issues of regulation in and access to foreign markets will rebound on domestic R&D decisions.

Cooperative research ventures like Sematech and the Semiconductor Research Corporation are a relatively new strategy

13. Figures are derived from National Patterns of Science and Technology Resources, 1986, *ibid.*, pp. 54, 59.

(NAE(1988)). The appeal to students of R&D is clear. Not only do they get around classic free rider issues (assuming all firms likely to benefit are involved), but they do so without restricting results. However, they have a feature in common with government development programs that are likely to limit their ultimate success. As big, prestigious efforts, they are subject to distributive politics even if they are do not receive big government grants. To the extent that government takes credit for the facilities, they may become the same species of dinosaur created by other federal R&D bureacracies.

Consider, for example, the Clinch River Breeder Reactor, which, at its initiation was 80% funded by a cooperative industry effort. This figure quickly fell by the wayside, as did private management control of the enterprise. By the time the project was cancelled, it had not only consumed over \$2 billion, but it had also diverted resources from other federal nuclear fission programs. Even the breeder reactor program was scaled back to accommodate Clinch River, which went from an estimated two percent of the breeder budget to over forty percent.

The power of this example is unavoidable. Sematech, for example, is currently authorized to obtain half of its funding from the federal government, and has received appropriations of \$100 million for fiscal years 1988 and 1989. If private firms lose the circle-the-wagon-train mentality that international competition has elicited, it is possible, even probable, that the centers will come under increased federal control. Lack of

sustained expected success, however, does not detract from their potential among the options available.

Space communications research deserves special mention, because the government is likely to remain involved in the critical launch component for some years, and is inevitably party to international treaty negotiations. Relying on direct federal technology development programs contains a degree of futility. However, the government can use its control over launches to advantage, to aid private research efforts. A recent study concludes that it would be technically feasible for the NASA to allow some private R&D projects on unrelated satellite launches. (SAB (1988)) By doing so, it would lessen one of the barriers to research -- the expense, riskiness, and uncertain timing of dedicated R&D satellites.

The three cases discussed here -- deregulation, cooperative private research, and satellite piggy-back launches -- each address a response to market failure in the provision of research and development. The first case concerns the restraining influence of regulation and limited entry in a regulated market. The second concerns limited company resources and appropriability. Launch piggy-backs address a troubling feature of some types of R&D, which is that not only are substantial resources sometimes required, but some projects are indivisible (i.e., the whole thing can be lost when a component fails) so that risks to investors are high.

General recommendations can be formulated for government policy by extrapolating from these examples. Actions by the

government to clarify post-divestiture policies will rebound on private R&D investment decisions. Such actions are the most important component of R&D policy for the federal government, for increased competition in the industry has in fact reduced federal opportunities for effective direct R&D programs. Finally, a more narrow goal for government is to investigate ways to allow R&D experimentation by firms that do not involve large, discrete investment choices. The last involves specific products and clearly is not always possible; it is offered here as a general policy guideline.

A general conclusion of this analysis is that incoherence of government policy is unavoidable. Of course, specific instances of incoherence may be inexcusable, and may indeed be subject to repair. However, when policy creates conflict between either different sectors of the economy or between different firms within a sector, the political system is designed to produce conflicting policies. A challenge for government, as for industry, is to use the conflicts in aid of innovation.

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